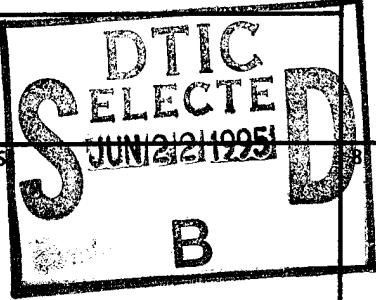# REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words)

This research focuses on applying mixed-integer programming (MIP) to selected problems of the U.S. Army. The research has two distinct aspects:
Phase 1: Methodology. Developing and implementing new methodology for solving general 0-1 MIPs. We have developed new theoretical results on complexity issues associated with cover inequalities and experimental results and algorithms on how to use them efficiently.
Phase 2: Applications. Working with the Concepts Analysis Agency (CAA) on the solution of specific large-scale MIPs and technology transfer. The current ongoing effort involves the solution of a model for Future USAREUR Site Selection for Reduction in Troops.

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Applications of Mixed-Integer Programming
to Problems of the U.S. Army

Final Report

George L. Nemhauser

March 28, 1995

U.S. Army Research Office

Research Agreement No. DAAH04-94-G-0017

Georgia Institute of Technology

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I.   Project Statement

The purpose of this contract was to conduct research to support the Concepts Analysis Agency (CAA) in the solution of large-scale mixed-integer programming models.

II.   Summary of Results

This research focuses on applying mixed-integer programming (MIP) to selected problems of the U.S. Army.   The research has two distinct aspects:

Phase 1: Methodology. *Developing and implementing new methodology for solving general 0-1 MIPs.*

Phase 2: Applications. *Working with the CAA on the solution of specific large-scale MIPs and technology transfer.*

Research in Phase 1.
It is well-known that tremendous improvements in solving large-scale and/or difficult MIPs has come from branch-and-cut algorithms i.e. strengthening branch-and-bound by the augmenting the linear programming relaxations at nodes of the search tree by cutting planes.   For general 0-1 problems, lifted cover inequalities are the most important class of cutting planes and have been implemented in widely used software. We have developed new theoretical results on complexity issues associated with cover inequalities and experimental results and algorithms on how to use them efficiently [Gu, Nemhauser and Savelsbergh, 1994a, 1994b]. Crowder, Johnson and Padberg, 1983].   The experimental work is implemented through the MINTO software system [Nemhauser, Savelsbergh and Sigismondi, 1994].

Cover inequalities have been extended to MIPs in the form of flow cover inequalities, but with limited success in practice.   We have recently discovered several generalizations of flow cover inequalities [Gu, Nemhauser, Savelsbergh, 1994c]. As explained in that extended abstract, subadditive functions play a key role in lifting lower dimensional facets to strong valid inequalities with respect to the full polyhedron. Lifting is normally required to obtain strong inequalities, but can be very computationally burdensome if the lifting is done exactly. We have discovered a powerful and very flexible lifting tool that uses subadditive functions to obtain good approximations to exact lifting.

Research in Phase 2.
The current ongoing effort involves the solution of a model for **Future USAREUR Site Selection for Reduction in Troops**. This model was communicated to us by Lieutenant Colonel Andrew G. Loerch of the Concepts Analysis Agency and we have worked with him on improving and solving the model. Significant progress has been made so that an initially intractable problem has become solvable for rather large size instances [Loerch et al, 1994]. Further work needs to be on this model so that larger problems can be solved and additional constraints can be included in the model.

Technology transfer is an important aspect of this work. We have provided CAA with our experimental branch-and-cut code, MINTO [Nemhauser, Savelsbergh and Sigismondi, 1994].

III. Publications

Z. Gu, G.L. Nemhauser and M.W.P. Savelsbergh, "Lifted Cover Inequalities for 0-1 Integer Programs I: Computation," LEC-94-09, School of Industrial and Systems Engineering, Georgia Institute of Technology, 1994a.

Z. Gu, G.L. Nemhauser and M.W.P. Savelsbergh, "Lifted Cover Inequalities for 0-1 Integer Programs II: Complexity," LEC-94-10, School of Industrial and Systems Engineering, Georgia Institute of Technology, 1994b.

Z. Gu, G.L. Nemhauser and M.W.P. Savelsbergh, "Sequence Independent Lifting of Cover Inequalities," Extended Abstract, School of Industrial and Systems Engineering, Georgia Institute of Technology, 1994c.

A. Loerch, N. Boland, E.L. Johnson and G.L. Nemhauser, "Finding an Optimal Stationing Policy for the US Army in Europe After the Force Drawdown," LEC-94-11, School of Industrial and Systems Engineering, Georgia Institute of Technology, 1994

G.L. Nemhauser, "The Age of Optimization: Solving Large-Scale Real World Problems", *Operations Research* 42, 5-13, 1994.

IV. Scientific Personnel

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Natashia Boland, Postdoctoral Fellow
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V. Reportable Inventions

None

The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official department of the Army position, policy, or decision, unless so designated by other documentation.